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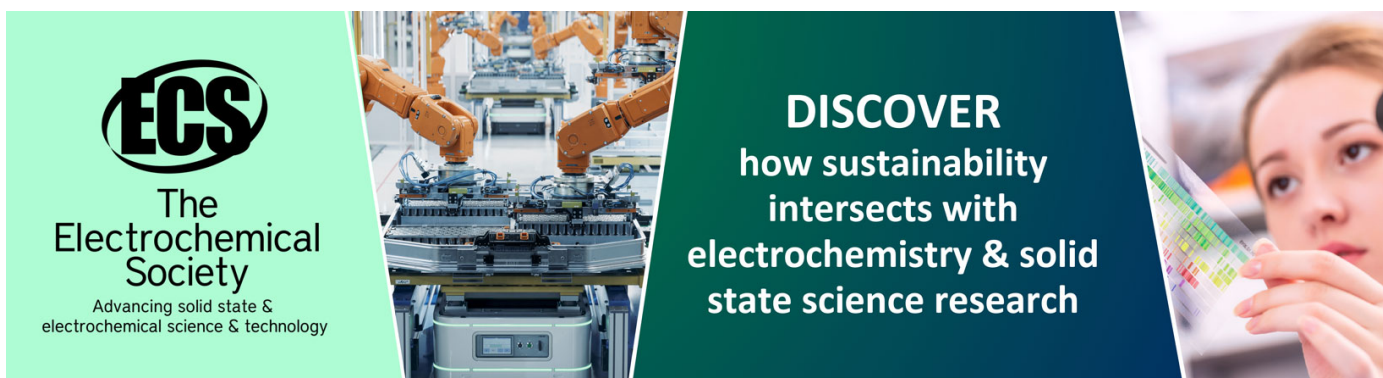
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Exothermic and Insulating Riser Design of Gear Ring Seat Casting based on Anycasting

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Abstract. According to the disadvantages of design method of traditional riser, this article introduces the design method of riser which is based on the computer aided engineering technology, the casting process of exothermic and insulating riser for steel casting of gear ring seat of excavator was simulated by Anycasting software. the riser modulus was directly calculated according to the solidification time of the casting by the simulation, Meanwhile its volume and quantity could be confirmed by the feeding liquid volume method. The result shows that the feeding effect of the exothermic and insulating riser design is perfect, The method can ensure no shrinkage defect in the casting, and also improve the technological yield, thus it is validated that the technique is feasible.

1. Introduction

The riser design of steel castings appears to be more complex and difficult due to many factors. Unreasonable designed may easily lead to many defects such as shrinkage and so on which directly affect the quality of castings and productivity. Modulus and thermal pitch circle method (ratio method) are mostly used in traditional riser system design. These methods all have their own limitations, especially unable to predict the casting solidification process, cannot consider the interaction of the molding materials, chills and riser and the impact on the casting solidification process. These methods have their limitations, especially unpredictable solidification process that does not consider the shape of the material and the cold iron and other interactions with the riser and the effect on the solidification process. In recent years, due to the development of casting CAE technology, the visualization of casting filling and solidification process can be achieved by computer and the reliability and rationality of riser design can be improved [1-4]. In this paper, the riser of gear ring seat steel casting is designed by means of the South Korean Anycasting simulation software based on the actual factory condition.

Exothermic/insulating riser sleeve is made of exothermic material and insulating material which combined the advantages of insulating riser and exothermic riser. When pouring process, exothermic reaction is produced when the exothermic material in exothermic/insulating riser sleeve in contact with the molten metal, the temperature of molten metal within the riser is increased. Then the insulating material begins to sinter, insulate and the heat is not easy to be lost, the molten metal



solidification time is extended, the riser size can be designed to be smaller compared to the insulating riser and exothermic riser. Exothermic/insulating riser sleeve can effectively improve casting quality and process yield, reducing the pressure of riser gas cutting and clearing processing workload, conform to the pursuit of the trend of near net shape casting industry, and is currently one of the most advanced technology in foundry industry.

2. Riser Design Method

There are several kinds of traditional riser design methods, modulus method, thermal pitch circle (ratio method), perimetrischen quotient method, the cubic equation method, etc. are commonly used. In recent years, the riser design method based on CAE technology appeared due to the development of casting CAE technology.

2.1 Thermal Pitch Circle Method

The cylindrical riser diameter or the circular waist width can be obtained when the pitch circle diameter of feeding position is enlarged by the a certain percentage based on the experience in thermal pitch circle method. In production, the thermal pitch circle method is widely used in the enterprise because of its convenience and is a method commonly used in riser design. Its advantage is simple calculation, but practical experience is needed due to the poor theory, a bigger safety factor is generally chosen when determining the riser proportion and the casting process yield is low.

2.2 Modulus Method

Use the square root law of modulus and solidification time, the riser modulus is a certain percentage greater than the modulus of the feeding position in order to ensure the final solidification of riser, and then make sure the riser has sufficient molten metal to feed the volume shrinkage of casting based on the feeding efficiency [5].

Modulus method is widely described in textbooks and scientific literature because of its clear physical meaning and simple derivation. However, it is often difficult to use in actual due to the complexity and the irregularity of casting parts.

2.3 Riser Design Method Based on CAE Technology

Riser design must meet the following criteria:

- (1) Riser and riser neck solidification time should be greater than or equal to the casting (or feeding positions) solidification time to ensure smooth passage of feeding. This principle applies to the casting alloy with directional solidification properties such as cast steel alloy (energy principles);
- (2) There must be adequate liquid metal to feed the casting (volume principle);
- (3) The potential energy of riser should be higher than the fed casting (potential energy principle).

If you know the solidification time of the casting (or feeded position) and riser, and the volume need to be fed of the casting, the problem is solved. The solidification time of the casting (or feeded position) t_c can be got by casting CAE simulation software. The solidification time of the riser t_r can be got according to the principle of energy, and then riser modulus can be calculated out. The riser size and the number can be calculated out according to the principle of volume. Simulation and constant correction are carried out on the computer, until there are no defects in the casting.

3. Casting Process Introduction

In this paper, the test object is a steel casting of gear ring seat which is a factory production of excavator, it's made of ZG270-500, the outer contour size is $1246 \times 1246 \times 170$ (mm), the weight is 372kg, the casting process is shown in Figure 1.

Bottom gating open casting system is used in the production. The molten steel flow along the tangent line from the bottom into the cavity and then rises smoothly, the sand flushing is small and not easy to form slag. Chills are placed at the top of casting, so that the casting ring hot section is uniformly cut off and easy to place oval exothermic/insulating riser.

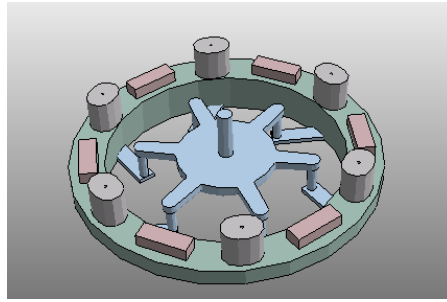


Figure 1. Casting process

4. Riser Process Design

4.1 Solidification Time

Test first for not joining in the riser of casting solidification simulation analysis, the result is shown in Fig.2: Due to the effect of chills, casting hot section in the middle of chills position and be cut off uniformly. The solidification time is 1764s. Through simulation, the final position of solidification and final solidification time can be predicted accurately which provide the basis for riser design.

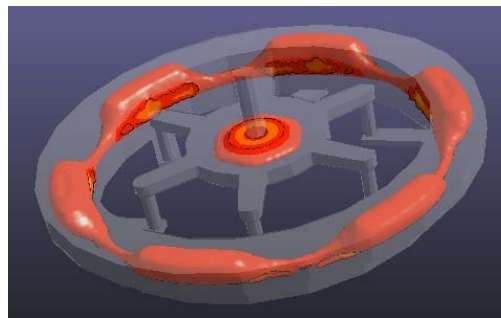


Figure 2. Casting solidification simulation

4.2 Solidification Time of Exothermic/insulating Riser

According to the Chvorinov formula, the relationship between the casting solidification time and modulus is:

$$t = kM^2$$

Where, t — Solidification Time(s); M — Modulus (mm); k — Solidification Factor (s/mm²), associated with alloy type, the same material is the same value.

Riser play the role of feeding and the energy principle is:

$$t_r > t_c$$

Where, t_r — Solidification Time of riser(s); t_c — Solidification Time of the casting (or feeded position) (s)

According to the conditions of the riser feeding effect for $t_r > t_c$, the solidification time of riser is set as 2000s temporarily. After several times simulation test of the oval exothermic/insulating riser, we know that the riser solidification coefficient is 3.65 and the effective modulus of the exothermic/insulating riser is 23.4 mm according to Chvorinov formula.

In addition to have appropriate modulus, riser design must also satisfy the principle of volume. The smallest volume of riser is decided according to the feeding area of casting volume which is called

feeding liquid method, this method can be used to check the volume of riser and determine the number of riser. The maximum casting volume that a certain feeding riser volume can feed is determined by equation

$$\eta \cdot V_r > \varepsilon \cdot (V_r + V_c)$$

Where: η — Riser feeding efficiency (%); ε — Volume shrinkage (%); V_c — Casting volume or the volume of the feeding area (mm³); V_r — Riser volume (mm³).

The riser feeding efficiency $\eta = 25\% \sim 45\%$, a larger value is chosen when the heat preservation ability is more capable. At the same time, the feeding efficiency also related to the shape coefficient of the casting, and the relation are shown in table 1, q is calculated by equation

$$q = V_c / M_c^3$$

Where: V_c — Casting volume (mm³); M_c — Casting modulus (mm).

Table1. Relationship of Riser feeding efficiency and casting shape factor

Casting shape factor q	<200	200	300	400	500~1000	>1000
Riser feeding efficiency η (%)	25	30	33	35	40	45

The computed result of this casting shape coefficient is 3654, therefore the feeding efficiency is 45%, according to the Casting Process Manual[6-10], the ZG270-500 volume shrinkage rate is 4.5%, the casting weight is 372 kg, thus calculate the riser weight should be 41.33 kg. Riser FT100 - T80/120/120 produced by Jinan Shengquan group co., LTD is used in this process, type, the long axis of the ellipse is 120 mm long, short axial length is 80 mm, and the height is 120 mm, the total number is 6. The riser individual weight is 7.1 kg and the gross weight is 42.6 kg which satisfy the volume principle.

Risers are placed at the top of the casting hot section which meet the energy principle. Solidification simulation analysis of the riser is shown in figure 3 which shows the actual solidification time is 2074 s.

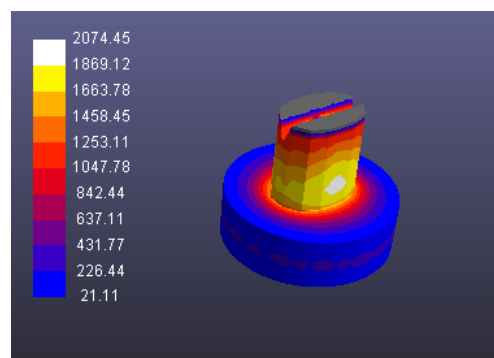


Figure 3. Solidification simulation of exothermic and insulating riser

4.3 Process validation

According to the above design and calculation, the filling and solidification simulation analysis of the casting process has been carried out. The final solidification area is located in exothermic and

insulating riser, which in line with the principle of riser design [11]. A small amount of shrinkage is found in the casting, the shrinkage cavity only appear in the riser and gating system, which doesn't affect the quality of the casting. The casting anatomy section produced by this process is shown in Figure 4, the casting quality is in good condition and no shrinkage cavity defects are found in the casting, which consistent with the simulation results.



Figure 4. Dissected casting

4.4 Design Scheme Comparison

The castings modulus can be calculated by simplified method as equation

$$M_r = 1.2 M_c$$

Where: M_r —— Riser modulus (mm); M_c —— Casting modulus (mm).

The casting modulus can be directly read by Anycasting software and the value is 23.65 mm, the required riser modulus is calculated according to the equation and the value is 28.38 mm, far more than the effective modulus of 23.47 mm selected in this paper, it is proved the riser is fully able to meet the need of castings feeding, and thus we can know that the riser modulus design method based on CAE numerical simulation is more accurate and easier [12-13]. Combined with chose heat insulating riser, the process scheme theory production rate of 74%, greatly save the liquid steel raw materials, at the same time can reduce the gas cutting riser and form processing workload, improve the production efficiency.

5. Conclusion

Through production verification, the feeding effect exothermic and insulating riser designed by riser design method based on CAE is good, not only ensure there're no casting shrinkage cavity defects, but also improve the technological production rate, and consistent with the simulation results, proved the feasibility of this method. The casting process design and optimization process are completed on the computer in this method, repeated trial production and process correction are not needed and thus save time and cost, make up for the deficiency of the traditional riser design method can be made up and the level of casting process design can be improved. At the same time, under the background of energy saving and emission reduction requirements in the casting industry, the pursuit of near net shape has become a target for foundry workers, new casting technology means such as exothermic and insulating riser greatly improved the casting production rate and production efficiency. The improvement of process design method and the use of new technology means is the path to improve the level of casting technology and realize green casting.

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